

# CLEO results on non- $D\bar{D}$ decays of $\psi(3770)$

Hajime Muramatsu

*Department of Physics and Astronomy, University of Rochester, NY 14627-0171*

**Abstract.** CLEO has recently measured the cross section for  $e^+e^- \rightarrow \psi(3770) \rightarrow \text{hadrons}$  at  $E_{\text{cm}} = 3773 \text{ MeV}$  to be  $(6.38 \pm 0.08^{+0.41}_{-0.30}) \text{ nb}$  which is consistent with other observations of non- $D\bar{D}$  decays of  $\psi(3770)$ .

## 1. INTRODUCTION

It has been almost 30 years since the Lead-Glass Wall measured the inclusive cross sections of  $D^0(\bar{D}^0)$  and  $D^\pm$  [1]. Since then, a few experiments have measured the cross section of  $e^+e^- \rightarrow \psi(3770) \rightarrow \text{hadrons}$  where  $\psi(3770)$  is the lightest charmonium resonance state, lying above the  $D\bar{D}$  threshold, and so should predominantly decay into  $D\bar{D}$  pair, analogous to the case of  $\Upsilon(4S) \rightarrow B\bar{B}$ . As it is apparent, for instance, by looking at a summary table given in Table 2 of [2] which also gives average of the four measurements on  $\sigma(\psi(3770) \rightarrow \text{hadrons})$  to be  $(7.9 \pm 0.6) \text{ nb}$ , there has been a debate on whether there is a relatively large production rate of non- $D\bar{D}$  decays of  $\psi(3770)$ .

With the advent of the CLEO-c phase of CLEO's program, this old puzzle is being readdressed. CLEO has already published the measurement of cross section of  $D\bar{D}$  [3]. I would like to report a new result from CLEO on the measurement of the cross section for  $\sigma(e^+e^- \rightarrow \psi(3770) \rightarrow \text{hadrons})$  using  $281 \text{ pb}^{-1}$  of the CLEO-c data along with other results on observations and searches for non- $D\bar{D}$  decays of  $\psi(3770)$  done by the same detector.

## 2. SEARCHING FOR NON- $D\bar{D}$ DECAYS OF $\psi(3770)$

The best way to look for possible non- $D\bar{D}$  decays of  $\psi(3770)$  is probably to look for the known dominant decay modes of  $\psi(2S)$  such as  $\psi(2S) \rightarrow \gamma\chi_{cJ}$ ,  $\psi(2S) \rightarrow \pi\pi J/\psi$ .

CLEO has measured  $\sigma(e^+e^- \rightarrow \psi(3770)) \times \mathcal{B}(\psi(3770) \rightarrow \gamma\chi_{c1})$  to be  $(20.4 \pm 3.7 \pm 2.4) \text{ pb}$  while their radiative transitions to  $\chi_{c0}$  and  $\chi_{c2}$  states were statistically insignificant, hence set upper limits [4]. We also have measured  $\sigma(e^+e^- \rightarrow \psi(3770)) \times \mathcal{B}(\psi(3770) \rightarrow XJ/\psi)$  where  $X$  being  $\pi^+\pi^-$ ,  $\pi^0\pi^0$ ,  $\eta$ , and  $\pi^0$  (the signal of  $\pi^0$  mode was not significant) [5].

Furthermore, we searched for two- and multi-body decays of  $\psi(3770)$ . In the search of two-body decays (vector-pseudoscalar), we looked for productions of  $\rho^0\pi^0$ ,  $\rho^+\pi^-$ ,  $\omega\pi^0$ ,  $\phi\pi^0$ ,  $\rho\eta$ ,  $\rho\eta'$ ,  $\omega\eta'$ ,  $\phi\eta'$ , and  $K^{*0}\bar{K}^0$  as well as  $b_1\pi$  ( $b_1^0\pi^-$  and  $b_1^+\pi^-$ ) from  $\psi(3770)$  decays [6]. A statistically significant signal was found only in the  $\phi\eta$  mode  $(2.4 \pm 0.6) \text{ pb}$ . In multibody searches, we looked for productions of combinations of

**TABLE 1.** Results of observations and searches of non- $D\bar{D}$  decays for  $\psi(3770)$ . All upper limits are set at 90% confidence level.

$X$	$\sigma(\psi(3770) \rightarrow X)$ (pb)
$\gamma\chi_{c2}$	$< 10.8$
$\gamma\chi_{c1}$	$20.4 \pm 3.7 \pm 2.4$
$\gamma\chi_{c0}$	$< 295$
$\pi^+\pi^-J/\psi$	$12.1 \pm 1.8 \pm 1.2$
$\pi^0\pi^0J/\psi$	$5.1 \pm 2.0 \pm 1.0$
$\eta J/\psi$	$5.5 \pm 2.1 \pm 1.4$
$\pi^0J/\psi$	$< 1.8$
two- (VP) and multi-body	$< 240$
$K_S^0 K_L^0$	$< 0.07$

$\pi$ ,  $K$ ,  $p$ ,  $\eta$ ,  $\omega$ , and  $\phi$ , considered 25 different final states, with and without strangeness and/or baryons [7]. None of them yielded statistically significant signals. We also looked for  $\psi(3770) \rightarrow K_S^0 K_L^0$  [8] which was motivated the signal seen in the decay of  $\psi(2S)$  [9]. Table 1 summarizes results of these observations and searches for non- $D\bar{D}$  decays of  $\psi(3770)$ .

### 3. MEASUREMENT OF $\sigma(e^+e^- \rightarrow \psi(3770) \rightarrow \text{hadrons})$

Table 1 suggests that  $\sigma(\psi(3770) \rightarrow \text{non-}D\bar{D})$  is much less than 1 nb. In this section we present a measurement of the cross section for  $e^+e^- \rightarrow \psi(3770) \rightarrow \text{hadrons}$ ,  $\sigma_{\psi(3770)}$ , at  $E_{\text{cm}} = 3773$  MeV, where  $\psi(3770)$  refers to the yield at  $E_{\text{cm}} = 3773$  MeV from  $c\bar{c}$  annihilation into hadrons, not including continuum production of  $q\bar{q}$  ( $q = u, d, s$ ) and not including radiative returns to  $\psi(2S)$  and to  $J/\psi$ .

We define  $\sigma_{\psi(3770)}$  as

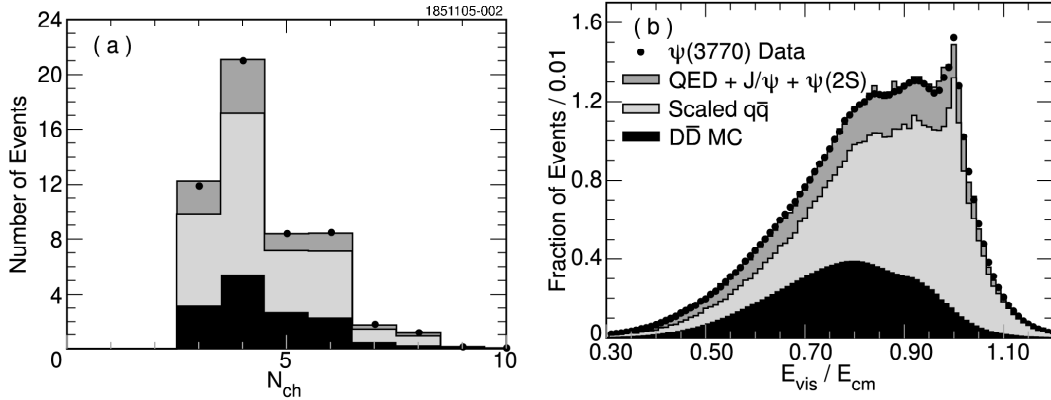
$$\sigma_{\psi(3770)} = \frac{N_{\psi(3770)}}{\epsilon_{\psi(3770)} \cdot \mathcal{L}_{\psi(3770)}}, \quad (1)$$

where  $\mathcal{L}_{\psi(3770)}$  is the integrated luminosity for the data taken at  $E_{\text{cm}} = 3773$  MeV ( $281.3 \pm 2.8 \text{ pb}^{-1}$ ),  $N_{\psi(3770)}$  is the observed number of hadronic events inferred to be directly from  $\psi(3770)$  decays, and  $\epsilon_{\psi(3770)}$  is the hadronic event selection efficiency of  $\psi(3770)$  decays.

Our main observable is the number of hadrons produced in  $\psi(3770)$  decays,  $N_{\psi(3770)}$ . At  $E_{\text{cm}} \sim 3773$  MeV, the main backgrounds come from continuum production  $e^+e^- \rightarrow q\bar{q}$  and radiative returns to  $\psi(2S)$  and  $J/\psi$ . Thus  $N_{\psi(3770)}$  can be given by

$$N_{\psi(3770)} = N_{\text{on-}\psi(3770)} - N_{q\bar{q}} - N_{\psi(2S)} - N_{J/\psi} - \sum_{l=\tau,\mu,e} N_{\ell^+\ell^-}, \quad (2)$$

where  $N_{\text{on-}\psi(3770)}$  is the observed number of hadronic events in the  $\psi(3770)$  data taken at  $E_{\text{cm}} = 3773$  MeV,  $N_{q\bar{q}}$  is the number of observed hadronic events from  $e^+e^- \rightarrow$



**FIGURE 1.**  $N_{\text{ch}}$  (a:left) and  $E_{\text{vis}}/E_{\text{cm}}$  (b:right) of our  $\psi(3770)$  sample that pass our hadronic event selection criteria (black-solid histograms). Backgrounds are also overlaid (generic  $D\bar{D}$  Monte Carlo, scaled continuum ( $q\bar{q}$ ) data, summed QED events ( $\sum_{l=e,\mu,\tau}(e^+e^- \rightarrow \ell^+\ell^-)$ ) plus radiative returns to  $\psi(2S)$  and  $J/\psi$ ). The yield of  $D\bar{D}$  Monte Carlo is scaled to the same size of the data assuming  $\sigma(e^+e^- \rightarrow D\bar{D} \rightarrow \text{hadrons}) = 6.4$  nb.

$\gamma^* \rightarrow q\bar{q}$ ,  $N_{\psi(2S)}$  and  $N_{J/\psi}$  are the number of hadronic events from  $\psi(2S)$  and  $J/\psi$  decays respectively, and  $N_{\ell^+\ell^-}$  is the number of events from  $e^+e^- \rightarrow \ell^+\ell^-$  that pass our hadronic event selection criteria. We subtract these backgrounds by employing scaled numbers of hadrons observed in two other data samples, taken at the  $\psi(2S)$  peak ( $E_{\text{cm}} = 3686$  MeV) and at the continuum below this resonance ( $E_{\text{cm}} = 3671$  MeV). Figure 1 shows the distributions of two of the important variables in our hadronic event selection criteria, track multiplicity ( $N_{\text{ch}}$ :left) and visible energy (charged and neutral) normalized to  $E_{\text{cm}}$  ( $E_{\text{vis}}/E_{\text{cm}}$ :right), of our  $\psi(3770)$  data sample that pass our hadronic event selection criteria (black-solid histograms). Also overlaid are various estimated and observed backgrounds. Notice that there is not much room between the black-solid histogram (data) and the total background.

The final cross section is  $\sigma_{\psi(3770)} = (6.38 \pm 0.08^{+0.41}_{-0.30})$  nb. The difference between  $\sigma_{\psi(3770) \rightarrow D\bar{D}}$  [3] and  $\sigma_{\psi(3770)}$  is  $(-0.01 \pm 0.08^{+0.41}_{-0.30})$  nb.

## REFERENCES

1. I. Peruzzi *et al.* (Lead-Glass Wall Collaboration), Phys. Rev. Lett. **39**, 1301 (1977).
2. J. Rosner, hep-ph/0411003.
3. Q. He *et al.* (CLEO Collaboration), Phys. Rev. Lett. **95**, 121801 (2005).
4. T.E. Coan *et al.* (CLEO Collaboration), hep-ex/0509030 (submitted to Phys. Rev. Lett.).
5. N.E. Adams *et al.* (CLEO Collaboration), hep-ex/0508023 (submitted to Phys. Rev. Lett.).
6. G. Adams *et al.* (CLEO Collaboration), hep-ex/0509011 (submitted to Phys. Rev. Lett.).
7. G. S. Huang *et al.* (CLEO Collaboration), hep-ex/0509046 (submitted to Phys. Rev. Lett.).
8. D. Cronin-Hennessy *et al.* (CLEO Collaboration), (in preparation to submit to Phys. Rev. Lett.).
9. S. Dobbs *et al.* (CLEO Collaboration), (in preparation to submit to Phys. Rev. Lett.).